REMARKS/ARGUMENTS

The subject invention relates to improvements in optically pumped semiconductor lasers (OPS lasers). The first semiconductor lasers were monolithically formed and excited with electricity. Beginning in the early 1990's, efforts were made to develop semiconductor lasers which were optically pumped. In a typically design, a semiconductor gain structure having a plurality of active gain layers is formed on a mirror structure. The mirror structure is used to define one reflector of the laser resonator. A second mirror, spaced from the semiconductor gain structure, is used to complete the resonator.

The devices reported in the literature through the mid-1990's were experimental in nature and generated very low output powers. For example, Kuznetsov reported a maximum fundamental output power of only about 700mw. Late in 1998, Alford reported a frequency doubled output of only 5mw. At this same time, the applicants were developing the first, commercial high power OPS devices. As described in the subject specification, applicants were able to operate devices having a fundamental output power of 10 watts and a frequency doubled output of 5 Watts, in both cases, at least an order of magnitude greater than performances reported in the cited art.

In one aspect of the subject invention, frequency doubling efficiency was increased using a folded resonator design as illustrated, for example, in Figure 1. In this resonator configuration, an extra fold mirror 26 is provided which when coupled with the end mirror 28, defines a branch of the resonator, separate from the OPS structure. The non-linear crystal is advantageously positioned in this branch of the resonator. This arrangement allows the mode size of the beam at the non-linear crystal to be optimized. Some of the pending claims have been amended to more clearly describe this aspect of the invention.

Turning to the Office Action, the Examiner objected to the use of element #37 in the specification at page 34, line 22 in reference to Figure 6. Applicants have amended the specification to correctly refer to element #35 which defines the common axial path of the laser resonators. The Examiner objected to claim 56 because it recited an incorrect dependency. This error has been corrected. Finally, the Examiner noted that claim 69 was a duplicate of claim 68. Claim 69 has been cancelled.

With respect to the prior art, the Examiner first rejected claims 53 and 58 as being anticipated by the Alford article "*Intracavity frequency doubling of an optically-pumped,*

external-cavity surface-emitting semiconductor laser," Advanced Solid State Laser Conference, Sandia National Laboratories, SAND-98-2108C, CONF-990105, December 31, 1998. The Examiner stated that Alford discloses active layers having a composition $In_x Ga_{1-x} N$. In fact, the active material Alford used was InGaAs. There in no mention of the InGaN material in Alford. As discussed in the specification, InGaN active layers can be used to directly generate blue light at 425 to 550 nm. It is respectfully submitted that Alford's teaching of InGaAs fails to anticipate or render obvious claim 53 nor any of the claims depending therefrom.

The Examiner rejected claims 45-47 and 52 based on the article by Rosiewicz "*Optical pumping improves VCSEL performance*," Laser Focus World, June 1997, in view of the Alford article. Claim 45 recites a ***frequency doubled*** output of at least 100mw. In contrast, Rosiewicz merely discloses a ***fundamental*** output of 600mw. It is well known that the fundamental output of a particular laser will be much higher than a frequency doubled output. As noted above, the highest reported frequency doubled output in the cited art (Alford) is a mere 5mw. Therefore, it is believed that claim 45, which specifies a frequency doubled output of at least 100mw, is not anticipated nor rendered obvious by Rosiewicz and Alford, whether taken alone or in combination.

Dependent claims 48 and 49 were further rejected based on the patent to Selker (5,485,482). Selker, which relates to a conventional laser with a solid state gain medium, was cited merely for its teaching of the mode quality of the beam. Selker cannot, however, overcome the deficiencies of Rosiewicz and Alford in rendering obvious claim 45 which covers an OPS laser generating a frequency doubled output of greater than 100mw.

Dependent claims 50 and 51 were further rejected based on the patent to Tsunekane (5,870,415). Tsunekane, which also relates to a conventional laser with a solid state gain medium, was cited for its teaching of the use of birefringent filter. Tsunekane cannot, however, overcome the deficiencies of Rosiewicz and Alford in rendering obvious claim 45 which covers an OPS laser generating a frequency doubled output of greater than 100mw.

Dependent claims 54 and 55 were rejected based on the Alford article and the Selker patent. As noted above, Selker, was cited merely for its teaching of the mode quality of the beam. Selker cannot, however, overcome the deficiencies of Rosiewicz and Alford in rendering obvious claim 53 which covers an OPS laser with active layers having a composition of $In_x Ga_{1-x} N$.

Dependent claim 56 and 57 were rejected based on the patent to Alford and Tsunekane. As noted above, Tsunekane was cited for its teaching of the use of a birefringent filter. Tsunekane cannot, however, overcome the deficiencies of Alford in rendering obvious claim 53 which covers an OPS laser with active layers having a composition of $In_x Ga_{1-x} N$.

Claims 59 and 60 were rejected as being unpatentable over Rosiewicz in view of Mooradian (5,131,002). Claim 59 covers an optically pumped OPS laser generating a fundamental output power greater than 2 watts. The patent to Mooradian was cited for its teaching of an OPS laser having an output which can be "over 100 Watts." However, the reference to ">100 W average" in the Mooradian text is simply a statement of what ***might*** be achieved if such a system was ever built and scaled up. In fact, the Mooradian patent includes no experimental data whatsoever and there is no indication that the relatively complex devices described therein were ever built. It is believed that the mere recitation of a possible wished for goal in a patent is not sufficient to be used in a obviousness rejection.

Nonetheless, and in order to expedite prosecution, applicants have amended claim 59 to structurally distinguish over the Mooradian reference. More specifically, claim 59 now recites that only a "single region" of the OPS structure is optically pumped. In contrast, in the first embodiment of Mooradian's system as shown in Figure 1, the OPS structure takes the form of a planar wafer which is pumped at multiple locations with multiple pumps sources in order to achieve higher powers. In a second embodiment as shown in Figure 2, a plurality of chips are stacked in a manner to allow pumping from both sides. It is respectfully submitted that amended independent claim 59, in which an OPS laser is configured to generate a fundamental output of greater than 2 watts, while the OPS structure is pumped at only a single region, is not anticipated nor rendered obvious by the Rosiewicz and Mooradian references.

It should be noted that in many of the illustrated embodiments of applicants' invention, the OPS structure is pumped with light from more than one source. However, the output from the multiple sources is directed to be substantially overlapping on the OPS surface. It is intended that this configuration be covered by the amended claim limitation of delivering the pump light to a substantially single region on the gain structure.

Claims 61-63, 65-67 and 70-72 were rejected as being obvious based on the article by Alford in view of Mooradian. Claims 61 and 65 have been amended to more particular point out and distinctly define the invention. More specifically, claims 61 and 65 have been amended to

recite that two of the reflectors are arranged to form a resonator branch segment separate from the OPS structure. Further, the non-linear crystal is located in that branch. As noted above, this arrangement allows the mode size of the beam at the non-linear crystal to be optimized.

Neither Alford nor Mooradian teach the use of a folded resonator system. In the Office Action, the Examiner relied on various other references to teach folded resonators, including Deacon (5,206,868) and Liu (4,048,515). Although the latter references teach different folded resonators, it is submitted that one skilled in the art would not have been motivated to combine those teachings with the primary references to reach applicants' claimed laser for the following reasons.

First, of all the cited art on optically pumped OPS lasers, only the article to Alford specifically teaches the use of a non-linear crystal. In Alford, the crystal is actually part of the resonator structure. More specifically, a potassium niobate crystal is aligned with the OPS structure. The outside surface of the crystal is provided with a reflective (HR) coating at the fundamental wavelength. This coating must be at least partially transparent to the frequency doubled wavelength of 490nm. Thus, Alford teaches a compact system with a minimum of optical elements. Since the crystal and the resonator are combined in a single element of Alford, one skilled in the art would not be motivated to add a fold mirror and move the doubling crystal into a completely different branch. It should also be understood that applicants' developments occurred back in 1999 when OPS lasers were first being investigated. What might seem an obvious modification today would be far less so when the early OPS devices were first being developed and tested. This is especially the case where the rejection is predicated on the combination of three and even four different prior art references to meet the claim limitations.

For the reasons set forth above, it is respectfully submitted that amended independent claims 61 and 65, which cover a frequency doubled OPS laser wherein the resonator includes a pair of additional reflectors to define a branch segment and wherein the non-linear crystal is located in the branch segment, define patentable subject matter and allowance thereof, along with the claims depending therefrom, is respectfully requested.

It is noted that independent claim 70 has been amended in the same manner as independent claim 59 and the same arguments for patentability apply. Dependent claims 62, 63, 66, 67, 71 and 72 depend from one of the independent claims discussed above.

In the Office Action, claim 64 and 68 and 69 were rejected as begin unpatentable based on Alford, Mooradian and Deacon. Claim 64 was amended in the same manner as claims 61 and 65 and is believed patentable for the reasons set forth above. Claims 68 and 69 depend from claim 65 discussed above.

Claims 73 and 74 were rejected as being obvious based on Alford, Mooradian and Kuznetsov ("*High-Power (›0.5-W CW) Diode-Pumped Vertical-External-Cavity Surface-Emitting Semiconductor Lasers with Circular TEM00 Beams*," IEEE Photonics Technology Letters, Vol. 9, No. 8, August 1997). Claim 73 defines an OPS laser which generates a ***frequency doubled*** output of greater than 100 milliwatts. As noted above, none of the cited art meets this limitation.

Claims 75 and 76 were rejected as being obvious based on Rosiewicz, Alford and Kuznetsov. Claims 75 and 76 have been cancelled rendering this rejection moot.

Claim 77 was rejected as being obvious based on Alford, Tsunekane, Kuznetsov and Liu. Claim 77 is limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. For at least the reasons set forth above with respect to claims 61 and 65, it is believed claim 77 defines patentable subject matter.

Claims 78 and 79 were rejected as being obvious based on Rosiewicz, Liu and Kuznetsov. Claim 78, like claim 77, is limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. For at least the reasons set forth above with respect to claims 61 and 65, it is believed claims 78 and 79 define patentable subject matter.

Claim 80 was rejected as being obvious based on Rosiewicz, Liu and Tsunekane. Claim 80, like claim 77, is limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. For at least the reasons set forth above with respect to claims 61 and 65, it is believed claim 80 defines patentable subject matter.

Claims 81-82 were rejected as being obvious based on Rosiewicz, Liu, Tsunekane and Holsinger (5,892,783) Claims 81 and 82, like claim 77, are limited to a laser having a resonator

with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. The patent to Holsinger was cited for its teaching of increasing the cavity length to increase the number of axial modes of the laser. Holsinger fails to overcome the deficiencies of the primary references, and for at least the reasons set forth above with respect to claims 61 and 65, it is believed claims 81 and 82 define patentable subject matter.

Claim 83 was rejected as being obvious based on Rosiewicz, Liu, Tsunekane and Shum (5,848,082). Claim 83, like claim 77, is limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. The patent to Shum was cited for its teaching of a diamond material used in a heat sink. Shum fails to overcome the deficiencies of the primary references, and for at least the reasons set forth above with respect to claims 61 and 65, it is believed claim 83 defines patentable subject matter.

Claims 84 and 85 were rejected as being obvious based on Rosiewicz, Liu Tsunekane, Shum and Holsinger. Claims 84 and 85, like claim 77, are limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. For at least the reasons set forth above with respect to claims 61 and 65, it is believed claims 84 and 85 define patentable subject matter.

Claim 86 was rejected as being obvious based on Rosiewicz, Liu, Tsunekane and Kuznetsov. Claim 86, like claim 77, is limited to a laser having a resonator with two branches wherein the OPS structure is located in one branch and the non-linear crystal is located in the other branch. Further, the fold mirror is used for out-coupling the frequency doubled radiation. For at least the reasons set forth above with respect to claims 61 and 65, it is believed claim 86 defines patentable subject matter.

In the Office Action, the Examiner rejected certain of the claims based on obviousness-type double patenting with respect to U.S. Patent No. 6,285,702. In response, applicants have included a terminal disclaimer to obviate this rejection.

In view of the above, it is respectfully submitted that all of the claims remaining in the application define patentable subject matter and allowance thereof is respectfully requested.

Respectfully submitted,

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